

Research & Technology

Evaluation of Zinc-Nickel Alloy Plating on Fasteners for Boeing Commercial Airplanes

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Background - Cadmium Plating Replacement

- Cadmium plating has been used traditionally on fasteners for its
 - Corrosion protection (sacrificial anodic)
 - Lubricity (anti-galling)
 - Electrical properties
- US and EU Environmental Regulations are mandating the Aerospace Industry to eliminate Cadmium and other toxic materials
- Current BCA Engineering practice allows substitution or replacement of Cadmium with Zinc-Nickel plating except for use on threads
- Use of Cadmium on Boeing commercial aircraft are allowed by Exemptions

Background - Cadmium Plating Replacement

- BR&T Chemical Technology and Fasteners Engineering have been evaluating the performance of Zinc-Nickel plating
 - Five test programs (Phases I to V) have been conducted to-date to compare the performance of Zinc-Nickel to Cadmium plating
 - Testing to-date has shown that acid and alkaline Zn-Ni plating are an acceptable replacement for Cadmium on threaded parts
 - Additional work is planned for Phase VI for 2011
 - Optimize coating thickness on threads
 - Fasteners (standard parts) qualifications are planned post Phase VI
 - BCA Programs have been evaluating electrical properties of Zinc-Nickel and found it acceptable for Bonding/Grounding applications

Six Phases of Fastener Evaluation

- **Acid Zinc-Nickel plating**
 - **Phase I - on 3/8" fasteners**
 - Axial Tensile Strength
 - Corrosion and Fatigue
 - Torque-Tension
 - Torque Effectivity and Reusability (Locking and Break-Away Torque)
 - **Phase II & III - on 3/8" fasteners**
 - Torque-Tension
- **Alkaline Zinc-Nickel Plating**
 - **Phase IV - on 3/8" fasteners**
 - Corrosion and Fatigue
 - Torque-Tension, Torque Effectivity and Reusability
 - **Phase V - on 3/16, 3/8 and 3/4" fasteners**
 - Similar to testing performed in Phase IV
 - **Phase VI - on various size fasteners**
 - Corrosion and Fatigue
 - Torque-Tension
 - Torque Effectivity and Reusability

The following results are available with representative data shown in this presentation

- **Corrosion**
- **Fatigue**
- **Tensile Strength**
- **Torque-Tension**
- **Torque Effectivity and Reusability (Locking and Break-away)**

Corrosion Test Results (All A286 Substrates)

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CC30AB5C



CC30AB5ZnNi



N10KE3B4CD



N10KE3B4ZnNi



LM6K16



LM6-16



LM6ZnNi16



HR162CD



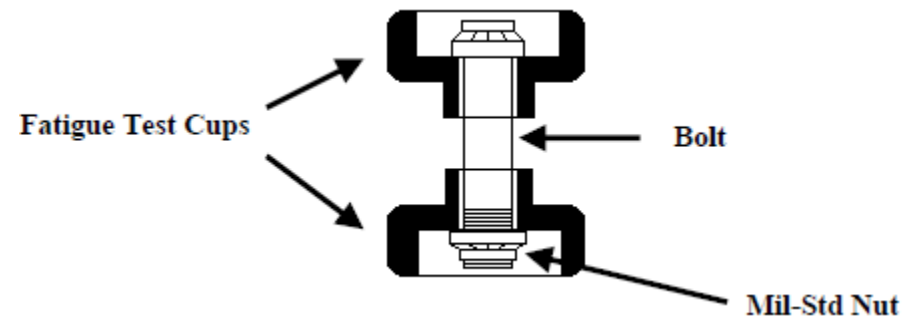
HR162ZnNi

Fatigue Test Results (Acid Zinc-Nickel, Phase I)

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- Nickel Alloy 718 Bolts – 3/8” diameter
Cd or Zn-Ni plated
- Test Nuts – MIL-STD-1312 uncoated
- Test setup – Per NASM1312-11
- Test parameters
 - Cycle = 24 Hz, RT
 - Tension-tension at 1090 lbs (low) and 10900 lbs (high)
- Requirement
 - Acceptance = 100000 cycles or meets statistical criteria
- Results – Acid Zn-Ni plating on fasteners performed comparable to Cd



BRIGHT CADMIUM BACB30US6P15		
TEST	CYCLES	LOCATION OF FAILURE
1	130,000	
2	130,000	
3	130,000	
4	130,000	
5	130,000	
6	130,000	
7	130,000	
8	89,314	THREAD
9	130,000	
10	130,000	
AVG	125931	

BOEING ACID ZINC-NICKEL BACB30US6K15		
TEST	CYCLES	LOCATION OF FAILURE
1	101,830	THREAD
2	73,749	THREAD
3	129,600	THREAD
4	130,000	
5	130,000	
6	130,000	
7	122,318	THREAD
8	130,000	
9	130,000	
10	130,000	
AVG	120750	

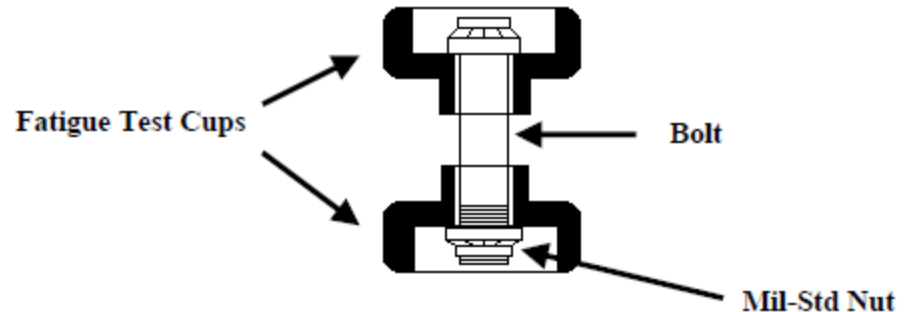
Req. Accept if the life of each fastener exceeds 100,000 cycles. Reject entire lot if average life is less than 65,000 cycles, or if one or more individual fasteners fails in less than 45,000 cycles. Take second sample if lot is not accepted or rejected on first sample.

Fatigue Test Results (Alkaline Zinc-Nickel, Phase IV)

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- Nickel Alloy 718 Bolts – 3/8” diameter
Cd or Zn-Ni plated
- Test Nuts – MIL-STD-1312 uncoated
- Test setup – Per NASM1312-11
- Test parameters
 - Cycle = 24 Hz, RT
 - Tension-tension at 1090 lbs (low) and 10900 lbs (high)
- Requirement
 - Acceptance = 100000 cycles or meets statistical requirement
- Results – Alkaline Zn-Ni plating on fasteners performed comparable to Cd



Part No.	Fastener Combination	
	Bolt	Nut
	BACB30US(Cadmium)	BACB30US(Zn-Ni)
	MIL-STD-1312	MIL-STD-1312
Test No.	Cycles	Cycles
1	130000	119410
2	130000	130000
3	130000	130000
4	130000	130000
5	130000	130000
6	130000	108618
Average	130000	124671

Fatigue Test Results (Alkaline Zinc-Nickel, Phase V)

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- A286 Hi-Loks – Cd or Zn-Ni plated
- A286 Collars – Cd or Zn-Ni plated
- Test setup – Per NASM1312-11
- Test parameters
 - Cycle = 24 Hz, RT
 - Size 5 – Tension-tension at 51 lbs (low) and 515 lbs (high)
 - Size 10 – Tension-tension at 192 lbs (low) and 1920 lbs (high)
- Requirement
 - Acceptance = 100000 cycles or meets statistical requirements
- Results – Alkaline Zn-Ni plating on fasteners performed comparable to Cd

FATIGUE TEST				
LOAD	SIZE 5 (.1640)	51 (MIN)	515 (MAX)	
	SIZE 10 (.3125)	192 (MIN)	1920 (MAX)	
PART NO.	FASTENER COMBINATION			
Bolt	BACB30FM5(Cd)	BACB30FM5(Cd)	BACB30FM5(ZnNi)	BACB30FM5(ZnNi)
Collar	BACC30AB5(Cd)	BACC30AB5(ZnNi)	BACC30AB5(Cd)	BACC30AB5(ZnNi)
TEST NO.	CYCLES	CYCLES	CYCLES	CYCLES
1	130000	130000	130000	130000
2	130000	130000	130000	130000
3	130000	130000	130000	130000
4	130000	130000	130000	130000
5	130000	130000	130000	130000
6	130000	130000	130000	130000
AVG.	130000	130000	130000	130000
Bolt	BACB30FM10(Cd)	BACB30FM10(Cd)	BACB30FM10(ZnNi)	BACB30FM10(ZnNi)
Collar	BACC30AB10(Cd)	BACC30AB10(ZnNi)	BACC30AB10(Cd)	BACC30AB10(ZnNi)
TEST NO.	CYCLES	CYCLES	CYCLES	CYCLES
1	130000	113419 HF	114307 HF	101367 HF
2	89251 HF	130000	130000	130000
3	130000	130000	100337 HF	100365 HF
4	130000	114210 HF	70148 HF	125260 HF
5	120357	130000	130000	130000
6	130000	124604	124638 HF	130000
AVG.	121601	123706	111572	119499

HF - Head Failure

Cd - Cadmium

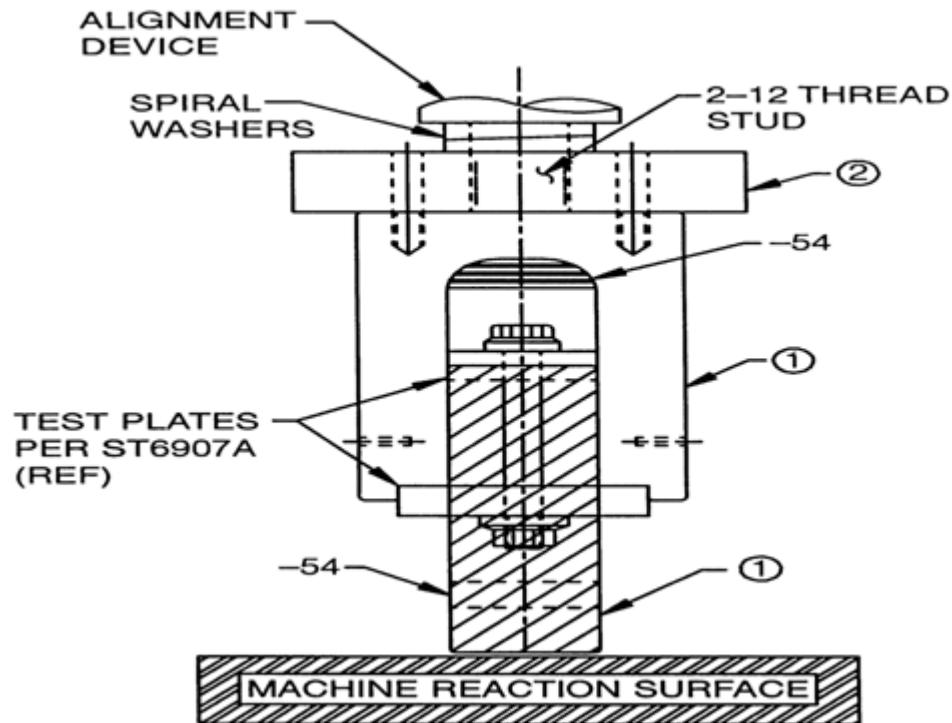
ZnNi - Zinc-Nickel

Tensile Strength Test Set-up (Acid Zinc-Nickel)

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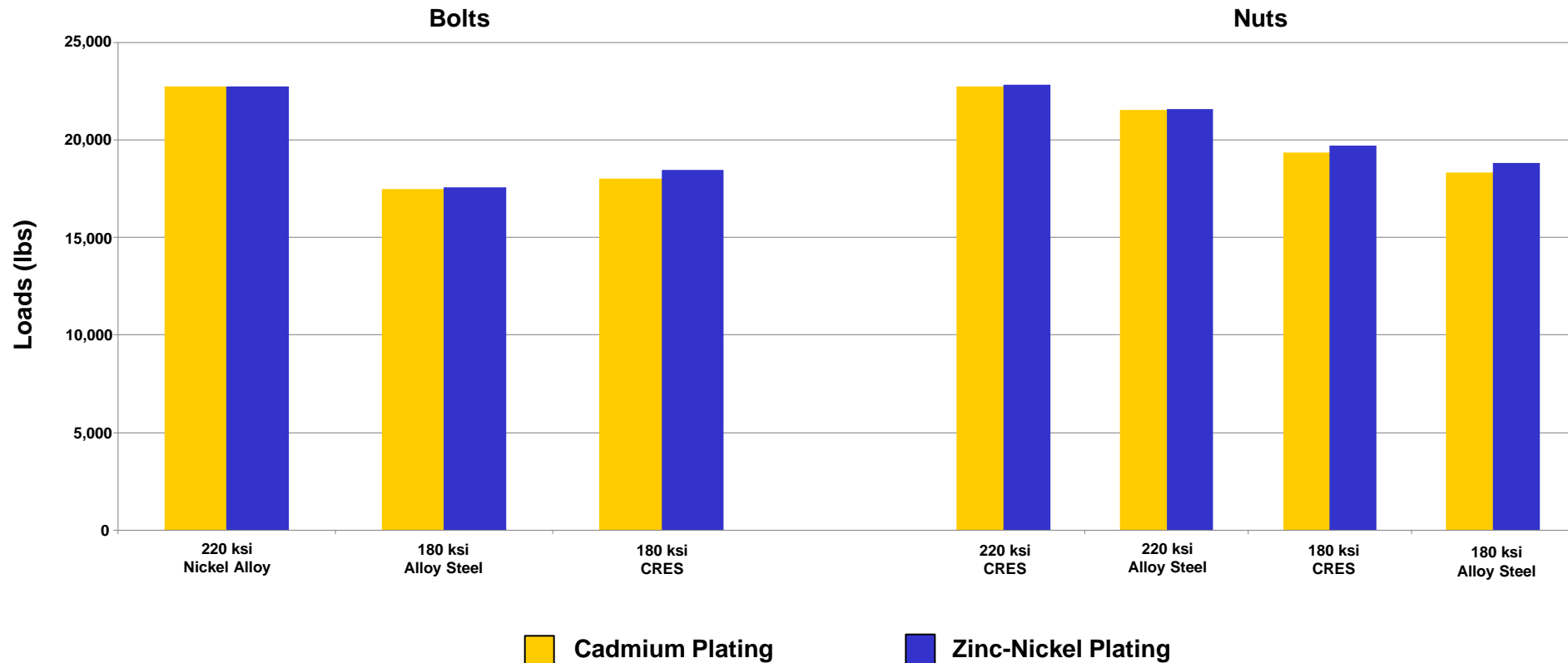
- Tensile Test performed in accordance with NASM1312-8



Tensile Strength Results (Acid Zinc-Nickel, Phase I)

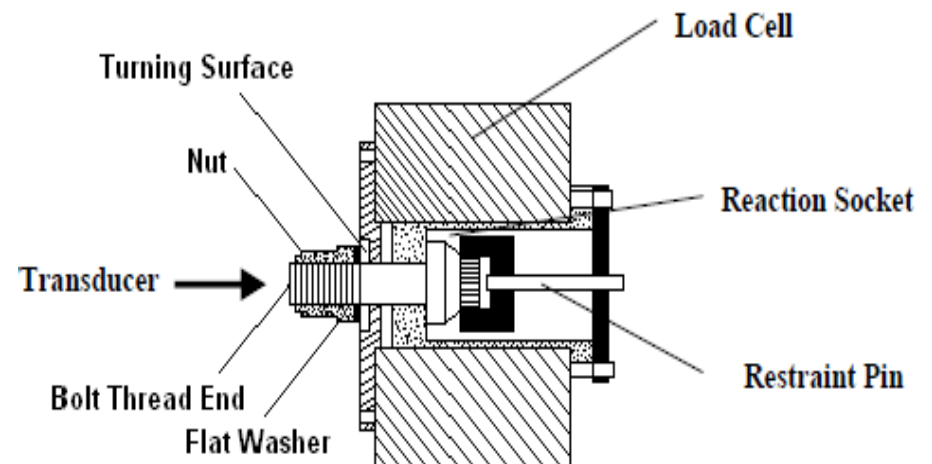
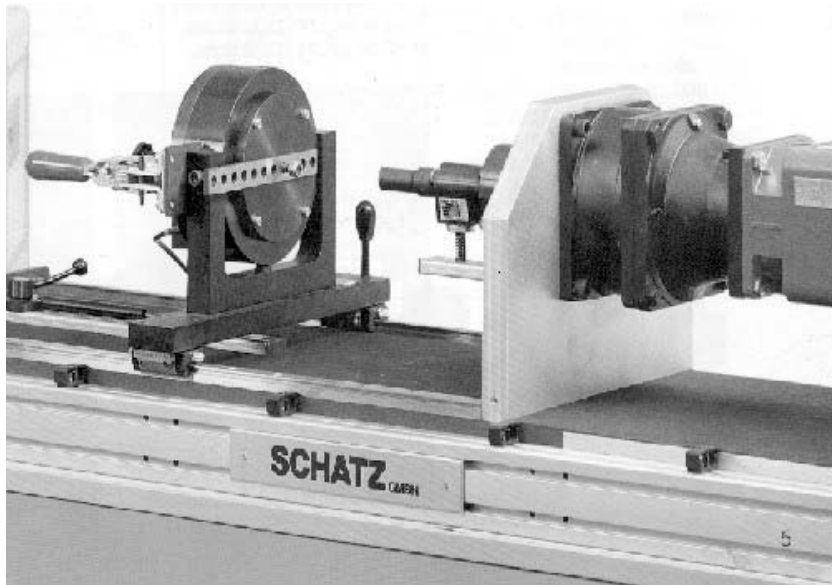
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Torque-Tension Test Set-up

- Performed Torque-Tension Test in accordance with NASM1312-15



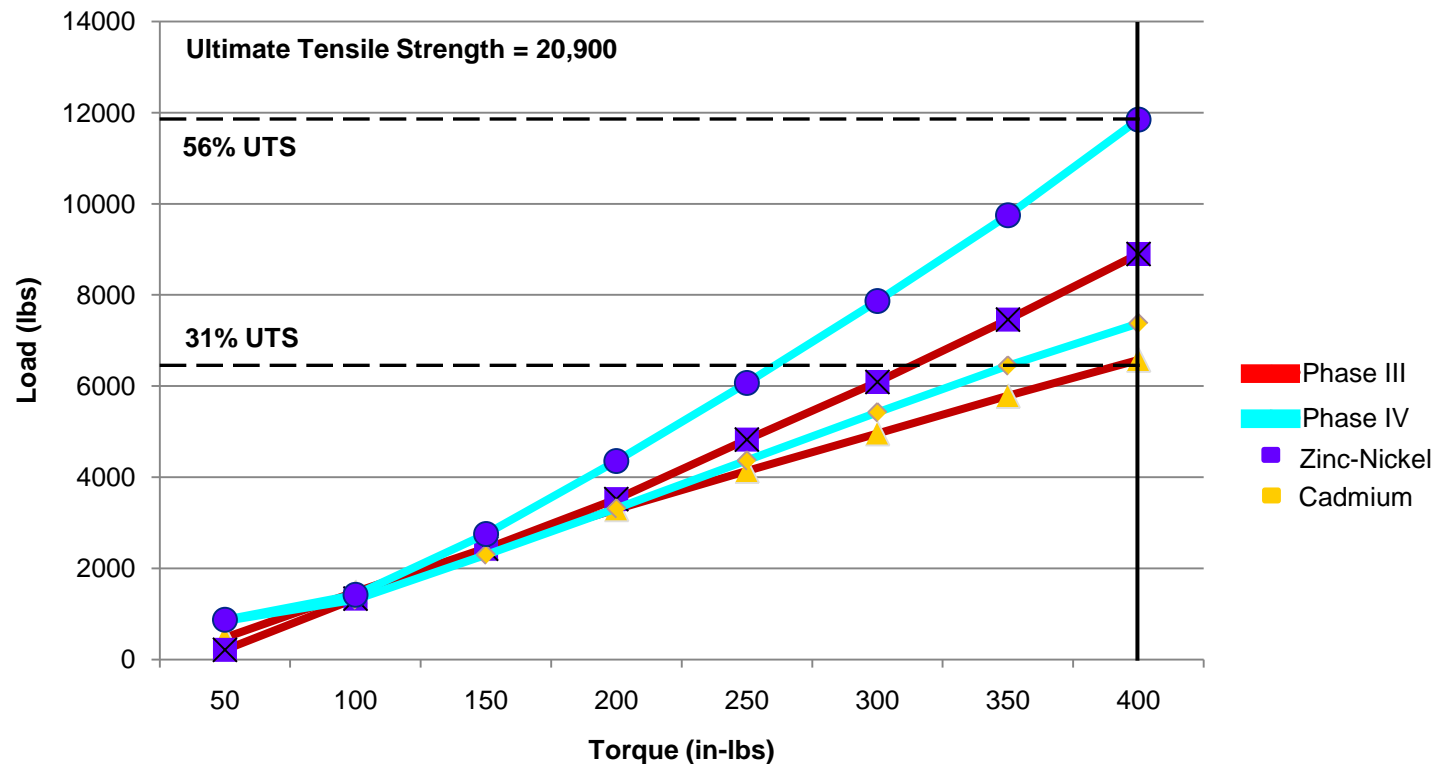
Torque-Tension Test Results for 3/8" Fasteners (Zinc-Nickel, Phase III and Phase IV)

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- Bolts - 3/8" Nickel Alloy 718 with BMS10-85 (Aluminum Pigmented Coating)
- Nuts - 3/8" A286 CRES with Cd or Zn-Ni plating and Solid Film Lubricant
- Washers - 3/8" A286 CRES with Cd or Zn-Ni plating
- **Requirement – At 400 in-lb torque, target tension 30% to 60% of Ultimate Tensile Strength (BAC5009)**
- **Result - Zn-Ni plated nuts/washers performed comparable to Cd for both Acid and Alkaline processes**

Torque-Tension



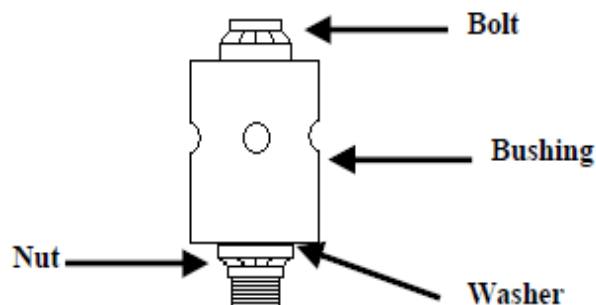
Locking Torque Test Results (Alkaline Zinc-Nickel, Phase V)

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- A286 Bolts – 3/8” diameter with BMS10-85 or Zn-Ni coating
- A286 Nuts – 3/8” diameter with Cd or Zn-Ni and Solid Film Lube
- A286 Washers – 3/8” diameter with Cd or Zn-Ni coating
- Test setup per BPS-N-70
- Requirement: 80 in-lbs MAX
- Phase V Results – Meets requirement. Similar to Cd.

Cycle	Average Locking Torque at Room Temperature							
	Configuration: Bolt + Nut + Washer							
	BMS + Cd + Cd	BMS + Cd + ZnNi	BMS + ZnNi + Cd	BMS + ZnNi + ZnNi	ZnNi + Cd + ZnNi	ZnNi + Cd + Cd	ZnNi + ZnNi + Cd	ZnNi + ZnNi + ZnNi
1	29	26	28	30	50	51	40	41
2	29	29	34	34	40	44	27	28
3	31	30	36	43	44	48	34	41
4	31	30	30	29	44	40	36	38
5	29	30	28	32	45	43	41	40
6	29	27	27	30	40	43	42	43
7	29	27	26	27	49	43	44	44
8	28	27	24	26	49	43	45	47
9	28	27	22	28	50	44	46	46
10	27	26	25	30	42	46	47	47
11	28	17	24	29	49	44	55	48
12	28	27	25	29	48	47	40	46
13	39	27	26	28	49	47	51	50
14	39	28	26	28	49	55	51	54
15	30	29	26	28	49	47	49	53



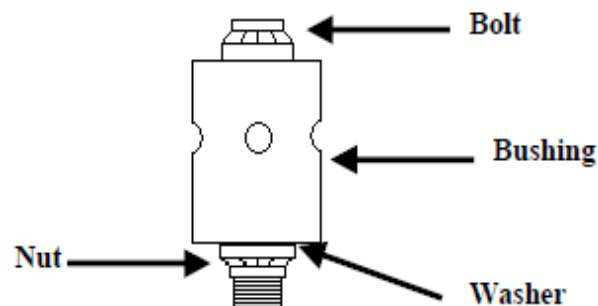
Break-away Torque Test Results (Alkaline Zinc-Nickel, Phase V)

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- **A286 Bolts – 3/8” diameter with BMS10-85 or Zn-Ni coating**
- **A286 Nuts – 3/8” diameter with Cd or Zn-Ni and Solid Film Lube**
- **A286 Washers - 3/8” diameter with Cd or Zn-Ni coating**
- **Test setup per BPS-N-70**
- **Requirement: 9.5 in-lbs MIN**
- **Phase V Results – Meets requirement. Similar to Cd.**

Cycle	Average Break-away Torque at Room Temperature							
	Configuration: Bolt + Nut + Washer							
	BMS + Cd + Cd	BMS + Cd + ZnNi	BMS + ZnNi + Cd	BMS + ZnNi + ZnNi	ZnNi + Cd + ZnNi	ZnNi + Cd + Cd	ZnNi + ZnNi + Cd	ZnNi + ZnNi + ZnNi
1	21	21	19	25	37	43	31	33
2	21	20	24	25	36	34	26	26
3	23	22	28	37	32	38	25	29
4	23	21	24	32	32	38	26	26
5	26	20	21	26	32	33	26	26
6	24	19	18	24	34	32	27	26
7	23	20	23	20	32	31	27	26
8	24	20	17	19	32	40	29	37
9	24	20	16	18	34	33	38	27
10	21	20	17	21	34	34	32	30
11	26	20	20	19	37	32	32	33
12	27	20	16	19	34	31	31	30
13	22	18	17	19	35	37	33	32
14	23	18	17	18	48	36	33	32
15	19	19	16	20	36	35	33	31



Conclusions

- **Corrosion**
 - Performed comparable to Cd
- **Fatigue**
 - Performed comparable to Cd
- **Tensile Strength**
 - Performed similar to Cd. Does not affect tensile strength of fasteners
- **Torque-Tension**
 - Performed similar to Cd for the 3/8" fastener system
 - Higher preload with historical scatter is anticipated for Zn-Ni plating
 - Current method (stripping & replating) is not optimized to provide proper plating thickness.
 - Additional testing will be performed in Phase VI with fasteners fabricated by the traditional manufacturing process (not strip and re-plate)
- **Locking and Break-away Torque**
 - Performed Similar to Cd

2011 On-going and Future Work – Phase VI

- **Torque-Tension**
 - **BACB30US (size 3, 6 and 16, Nickel Alloy w/ BMS10-85 or Zn-Ni)**
 - **BACB30NM (size 3, 6 and 12, Titanium Bolts)**
 - **BACB30LM (size 3,6 and 16, A286 Bolts)**
 - **BACB30MR, BACN11Z, BACW10BP (size 3, 6, and 12)**
 - Zip chem on bolts thread only
 - **BACB30FM, BACC30AB (size 5 and 10)**
 - Cetyl alcohol on Zn-Ni plated collars
 - Install on primed surface
- **Corrosion and Torque Effectivity (Ground Stud)**
 - **BACJ40AC (35 Amp Jumper Ass'y), BACS12HNS (A286 Screws)**
- **Push-in Installation Force of Hi-Loks fasteners**
 - **BACB30FM (size 5 and 10, A286 Hi-Lok)**
- **Push-in Installation Force with Rivet Gun of Hi-Loks fasteners**
 - **BACB30FM, BACC30AB (size 5 and 10)**
- **High RPM Installation Force with nuts runners**

Questions and Contact

- **Questions????**
- **What about other Zn-Ni coating?**
- **Thank you for the opportunity to share these data and to be part of your on-going discussion and evaluation of Cadmium plating alternatives**

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